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Description

[Flow Control in Conduits from Multiple Zones of a Well]

BACKGROUND OF INVENTION

[0001] It is common for wells to include multiple zones. A completion string positioned in a well to produce fluids from one or more zones may include casing, production tubing, packers, valves, pumps, and other components. One or more well sections may be perforated using a perforating gun string to create openings in the casing and to extend perforations into corresponding zones. Fluid flows from the zones through the perforations and casing openings into the wellbore and up the production tubing to the surface.

[0002] In many wells, sand control has to be performed to prevent the production of sand along with hydrocarbons through the production string. Sand control is typically accomplished by use of sand face completion hardware, which typically includes a sand screen. In a well having

multiple zones, the presence of certain completion hardware, such as sand face completion hardware, may complicate the placement of flow control conduits and flow control valves. The complexity of completion hardware associated with completing a well with multiple zones can lead to increased expenses associated with operating the well. Also, in some cases, the presence of completion hardware for multiple zones may prevent convenient intervention operations.

SUMMARY OF INVENTION

[0003] In general, enhanced methods and apparatus are provided to complete a well having multiple zones. For example, an apparatus for use in a well having at least three zones includes at least three sand control assemblies for positioning proximal respective zones. The apparatus further includes a flow assembly defining at least three flow conduits to respectively communicate with the at least three zones, where each of at least two of the flow conduits includes an annular path. At least three flow control devices respectively control flow in the at least three flow conduits.

[0004] Other or alternative features will become apparent from the following description, from the drawings, and from

the claims.

Brief Description of Drawings

[0005] Fig. 1 illustrates a completion string incorporating an embodiment of the invention.

[0006] Figs. 2A-2C are cross-sectional views of the completion string of Fig. 1.

Detailed Description

[0007] In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments are possible.

[0008] As used here, the terms "up" and "down"; "upper" and "lower"; "upwardly" and downwardly"; "upstream" and "downstream"; "above" and "below"; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly described some embodiments of the invention. However, when applied to equipment and methods for use in wells that are deviated or horizontal, such terms may refer to a left to right, right to left, or other relationship as appro-

priate.

[0009] Fig. 1 is a general view of a completion string positioned in a well 100. Although the well 100 depicted in Fig. 1 has one wellbore, it is contemplated that a well can have multiple bores, such as multilateral or branch bores. The well 100 has at least three zones 102, 104, and 106. In other implementations, the well 100 may have additional zones (such as four or more). The zones 102, 104, and 106 are stacked one above another generally along an axial direction of the wellbore 100. In this stacked arrangement, particularly when sand control equipment is used, it is sometimes difficult to provide flow conduits through the completion string in an efficient manner.

[0010] In accordance with some embodiments of the invention, three flow conduits 108, 110, and 112 are provided by a flow assembly in the completion string. In the implementation of Fig. 1, the first flow conduit 108 communicates with the zone 102 through a first sand control assembly 114. The second flow conduit 110 communicates with the second zone 104 through a second sand control assembly 116. The third flow conduit 112 communicates with the third zone 106 through a third sand control assembly 118. Note that in the depiction of Fig. 1, the zone 102 is

the most distal zone of the well from the well earth surface, whereas the zone 106 is the most proximal zone to the well earth surface.

[0011] The first flow conduit 108 extends through the inner bore of a tube or pipe. As used here, the term "tube"or "pipe"refers to an elongated structure that defines an inner bore. The elongated structure can be formed of one segment or of plural segments that are attached or coupled to each other. Although some embodiments of a "tube"or "pipe"are generally cylindrical in shape, other embodiments of a "tube"or "pipe" do not have to be cylindrically shaped. The terms "tube"and "pipe"are used interchangeably.

[0012] The second flow conduit 110 is an annular path that is defined outside of the tube that defines the first flow conduit 108. In some embodiments, the second flow conduit 110 is the annular path between a first tube containing the first flow conduit 108 and a second tube having a larger diameter than the first tube.

[0013] Similarly, the third flow conduit 112 is an annular path that is defined outside of the second tube. The third flow conduit 112, in some embodiments, is defined between the second tube and a third tube having a larger diameter

than the second tube. A portion of the third flow conduit 112 includes a wellbore annulus region 120, according to one embodiment.

[0014] Also shown in Fig. 1 are several packers 122, 124, 126, 128, 130, and 132. In other implementations, the number of packers can vary. The packers are provided to provide isolation between zones. Thus, any number of packers that provide adequate isolation between zones can be employed.

[0015] Flow control devices are also part of the completion string to control fluid flow in the flow conduits 108, 110, and 112. A first flow control device 134 controls fluid flow through the first flow conduit 108. In one implementation, the first flow control device 134 is a ball valve that is actuatable between an open position and a closed position. In other embodiments, other types of valves can be used in the flow control device 134. Examples of other valves include flapper valves, sleeve valves, barrel valves, and so forth.

[0016] A second flow control device 136 controls fluid flow in the second flow conduit 110. In one implementation, the second flow control device 136 includes a sleeve valve, although other types of valves can be used in other embod-

iments.

[0017] A third flow control device 138 controls fluid flow in the third flow conduit 112. Again, the third flow control device 138 is implemented as a sleeve valve in one embodiment. In other embodiments, the flow control device 138 can be implemented with other types of valves.

[0018] Each of the flow control devices 134, 136, and 138 is remotely actuatable by use of signals transmitted from the well surface to the flow control devices 134, 136, and 138. For example, the flow control devices 134, 136, and 138 can be electrically activated between open and closed positions. Electrical activation can be accomplished by using electrical lines run from the well surface to the flow control devices. Alternatively, hydraulic pressure can be used to control the flow control devices 134, 136, and 138. The hydraulic pressure can be communicated through control lines that are run from the well surface. Pressure pulses can also be transmitted through fluids in the wellbore to perform actuation of the flow control devices. Also, fiber optic lines can be run from the well surface, with optical signals transmitted through the fiber optic lines to control the flow control devices. Remote mechanical actuation can also be performed by use of

mechanical signals (such as by lifting and dropping a portion of the completion screen in a predetermined sequence to control activation of the flow control devices 134, 136, and 138). Wireless techniques, such as electromagnetic, seismic, and acoustic telemetry, may also be used to communicated with the flow control devices.

[0019] In other embodiments, the flow control devices 134, 136, and 138 are multi-position flow control device having at least one additional position between on and off.

[0020] Once activated, each of the flow control devices 134, 136, and 138 controls fluid communication between the flow conduits 108, 110, and 112, respectively, and a flow path 140 that extends upwardly, such as to the well surface through a production tubing.

[0021] Although not shown, sensors (e.g., flow rate sensors, pressure sensors, temperature sensors, etc.) can also be provided in the flow conduits 108, 110, and 112. The sensors are provided to measure characteristics associated with fluid flow from the zones 102, 104, and 106.

[0022] Figs. 2A-2C provide cross-sectional views of a portion of the completion string of Fig. 1. The bottom part of Fig. 2C shows the lower-most packer 122 and sand control assembly 114. The sand control assembly 114 includes two

sand screens 200 and 202 stacked one on top of the other. In other implementations, one sand screen can be used in the sand control assembly 114. Fluid flows from surrounding formation (of the first zone 102) through the sand screens 200 and 202 into an inner bore 204 defined by a first tube 206. Note that the first tube 206 includes many segments as depicted in Figs. 2A Rather than label each of these segments with a different reference number, the segments are referred to collectively as a "tube" 206. The segments of the tube 206 include all segments that define the inner bore 204, which is part of the first flow conduit 108. An isolation sub 208 includes a ball valve 210. During run-in of the completion string, the ball valve 210 is in a closed position. However, once the completion string is installed, the ball valve 210 is opened and kept open during production. The ball valve 210 has a bore through which intervention equipment can pass.

[0023] The inner bore 204 (and first flow conduit 108) extend through the packer 124 that is located above the isolation assembly 208. The flow conduit 108 also extends through another packer 126 located above the packer 124. The packer 126 is connected to the second sand control assembly 116, which also includes a sand screen 212. As

shown at the top part of Fig. 2C, flow from the surrounding formation (in zone 104) passes through the sand screen 212 into an annular path 214 that is defined outside the tube 206 defining the first flow path 108. The annular path is defined between the first tube 206 and a second tube 216 (Fig. 2B) that has a larger diameter than the first tube 206. The second flow conduit 110 extends through the annular path between the first tube 206 and the second tube 216. As with the first tube 206, the second tube 216 also includes multiple segments, which are collectively referred to as "tube"216.

[0024] The first and second flow conduits 108 and 110 extend through the next upper packer 128. The packer 128 is connected to the third sand control assembly 118, which includes a sand screen 218. Fluid flows through the sand screen 218 into an annular path 220 defined between the second tube 216 and a third tube 222. The annular region 220 is part of the third flow conduit 112. The first, second and third flow conduits extend through the next packer 130.

[0025] In one embodiment, at least portions of the first, second, and third tubes have a common axis. In other words, these portions of the first, second, and third tubes are

concentric.

[0026] The third flow conduit 112 extends into the well annulus 120 outside the second tube 216. The ball valve 134 is located in the first flow conduit 108 (see the upper part of Fig. 2B) to control fluid flow between the first flow conduit 108 and the flow path 140 in a production tubing. The ball valve 134 is remotely actuatable to rotate between open and closed positions. A sleeve valve 136 is provided slightly above the ball valve 134 to control fluid flow in the second flow conduit 110. The sleeve valve 136 is slidable up and down (by remote actuation) to enable opening and closing of a port between the annular path 214 and the flow path 140.

[0027] As depicted in Fig. 2A, the third flow conduit 112 extends through the well annulus 120 to the sleeve valve 138, which is slidable up and down (by remote actuation) to open and close ports between the well annulus 120 and the flow path 140.

[0028] In operation, depending on which of the zones 102, 104, and 106 are to be produced, one of the flow control devices 134, 136, and 138 is actuated to the open position, while the remaining two flow control devices are maintained in the closed position. Alternatively, if multiple

zones are to be produced, then two or more of the flow control devices 134, 136, and 138 can be opened, with fluids from the multiple zones commingled for production in the flow path 140 to the well surface. In other implementations, instead of producing fluids from zones 102, 104, and 106, injection can be performed in which fluid is injected into one or more of the zones 102, 104, and 106. In similar fashion, the flow control devices 134, 136, and 138 control injection of fluids into respective zones 102, 104, and 106.

[0029] Another valve can also be stacked in the lower completion (such as below sand control assembly 114) to incorporate flow from an additional zone, if desired. Such valve would provide selective fluid communication between the additional zone and the flow conduit 108.

[0030] By using the flow assembly according to some embodiments of the invention, convenient placement of flow control devices in conjunction with sand control equipment can be accomplished. Also, by using the flow assembly according to some embodiments, intervention operations are made more convenient.

[0031] While the present invention has been described with respect to a limited number of embodiments, those skilled

in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. For instance, the present invention may be installed in a land as well as a subsea wellbore. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.